probable relations of the atoms in the molecule, and the probability that the $Fe''S_2$ is entirely saturated.

A structural formula for marcasite might be given as: $Fe\begin{smallmatrix}S\\|\\S\end{smallmatrix}$ and this really expresses our entire knowledge of its constitution. It may be any polymer of this, for being unsaturated it should be capable of forming polymers.

I much regret that want of time has compelled me to discontinue these latter investigations into the decomposibility of these minerals by solutions of metallic salts under pressure, as it seems to open up a way for the study of many other sulphides and would doubtless be productive of most valuable results. Besides this it would probably adduce additional proof of the correctness of my formulas for these minerals as given above.

ACKNOWLEDGMENT.

I take this occasion to express my sense of gratitude to Prof. Edgar F. Smith, who suggested the work to me, and who by his constant encouragement and ready advice has greatly furthered its prosecution. Many of the experiments were made at his suggestion, and no doubt the success of the work is largely due to him.

Notes on the Osteology of Agriochœrus Leidy (Artionyx O. & W.)

By W. B. Scott, College of New Jersey, Princeton.

(*Read before the American Philosophical Society, May 18, 1894.*)

Leidy described this genus more than forty years ago, and yet in spite of the repeated explorations of the White River and John Day beds, it has hitherto been known only from the skull. In 1893, Osborn and Wortman published, under the name of *Artionyx*, an account of an extraordinary hind foot, which, with a typical artiodactyl tarsus, possesses five digits and very large claw-like ungual phalanges. The authors named refer *Artionyx* to the Ancylopoda on account of the resemblance of its phalanges to those of *Chalicotherium*. An examination of the type specimen of the supposed new genus led me to believe that it represented the hind foot of *Agriochœrus* (see Osborn's *Rise of the Mammalia in North America*, p. 44, separatim). This conclusion was founded upon the fact that the tarsus is not only artiodactyl, but characteristically oreodont in structure, and that certain features of the skull and dentition of *Agriochœrus* indicated that it must be an exceedingly aberrant member of the oreodont group.

Mr. J. B. Hatcher, curator of vertebrate paleontology in the Princeton Museum, has just sent me from the White River bad lands of South Dakota three fragmentary skeletons of *Agriochœrus*, associated with

teeth, the examination of which has yielded some very surprising results. Not only is the conjecture confirmed that *Artionyx* and *Agriochœrus* are synonymous names, but also that the forelimb which I described as ? *Mesonyx dakotensis* (*Proc. Acad. Nat. Sci.*, Phila., 1892, p. 306) probably belongs to some nearly allied form. *Agriochœrus* has thus almost as many synonyms as *Chalicotherium*, and as in that animal its various parts have been referred to no less than three mammalian orders, the head to the artiodactyls, the fore foot to the creodonts and the hind foot to the Ancylopoda.

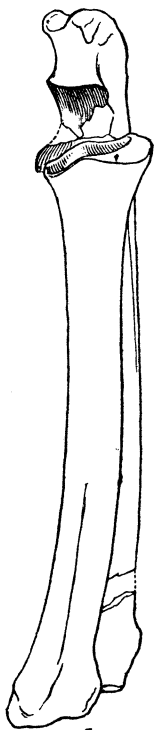

Fig. 1

FIG. 1. Left ulna and radius of *A. major?* ⅔ nat. size. The ulna is too much shortened in the drawing.

These preliminary notes will deal only with some of the more salient features of structure, leaving a complete account of the skeleton for another occasion. Beside the three parts of skeletons already mentioned, the material at present available consists of the fore leg and part of manus, lacking ungual phalanges, of the specimen described as ? *Mesonyx dakotensis* (Museum No. 10492), and a second very similar specimen collected last summer by Mr. Hatcher (No. 10695).

The skull of *Agriochœrus* departs very little from that of the oreodonts, even those features in which it differs from the White River members of that family, such as the open orbit and (probably) the absence of the lachrymal pit, being shared by *Protoreodon* of the Uinta Eocene.

The dentition displays the preëminently characteristic feature of the oreodonts in the conversion of the inferior canine into a functional incisor, while $\underline{p.\ 1}$ assumes the form and function of the canine. In other respects the dentition is widely different from that of the oreodonts. Briefly stated, these differences are as follows: (1) The reduction of the upper incisors; (2) the molariform pattern, more or less complete, of p. 4 in both jaws; (3) the structure of the molars, which closely resemble those of *Hyopotamus*, though lacking the protoconule in the upper series. These differences induced Leidy to refer *Agriochœrus* to a family distinct from, but allied to the oreodonts.

The proximal end of the radius is almost exactly like that of *Oreodon;* it is transversely extended, occupying the whole width of the humeral trochlea and antero-posteriorly compressed. The proportions of the three humeral facets are slightly different from those of *Oreodon*, the outer one being relatively narrower and the pit for the intercondylar ridge of the humerus larger and deeper. This applies, however, only to the large species from the upper beds; in *A. antiquus* the correspondence of this por-

tion of the radius with that of *Oreodon* is complete. The shaft has a remarkably strong curvature forward (*i. e.*, with the convexity in front) and is slender with transversely oval section, broadening gradually to the distal end, while in *Oreodon* it continues slender and expands suddenly into the inferior end. The distal portion presents many more points of difference between the two genera than does the proximal and has in *Agriochœrus* quite a deceptively carnivore-like appearance. In the latter it is more thickened transversely and less anteroposteriorly than in *Oreodon*, the scaphoid and lunar facets are less distinctly separated and of different shape and there is no sulcus for the extensor tendons upon the anterior face of the bone. The ulna has an olecranon shaped much like that of *Oreodon* and similarly grooved at the extremity, but decidedly thicker and more massive. The inner humeral facet forms in its distal portion a remarkably prominent flaring lip, far exceeding the corresponding structure in *Oreodon*. The shaft is large throughout; proximally it is trihedral, but soon becomes much compressed laterally and resembles a rib in shape, since the antero-posterior depth is retained. The distal end is contracted to a narrow and simply convex facet for the cuneiform.

The carpus is very different from that of *Oreodon*. A complete account of it cannot yet be given, the only available specimens lacking the scaphoid and pisiform. The lunar is more like that of the Uinta genus *Protoreodon* than that of the White River form. The special peculiarity of the lunar in the true oreodonts lies in its tendency to move over upon the unciform and to make its contact with the magnum altogether lateral. This tendency is already beginning in *Protoreodon* and reaches its culmination in *Merycochœrus* and *Merychyus*. In *Agriochœrus*, on the other hand, this tendency is reversed; the lunar rests almost entirely upon the magnum, its facet for which is broad and but slightly oblique. The anterior portion of this facet is convex, becoming deeply convex behind. The unciform facet is lateral rather than distal in front, but towards the palmar side the unciform extends beneath the lunar. The radial surface is like that of *Oreodon*, but does not descend so low upon the dorsal face of the bone, and the palmar portion does not present so much laterally. The cuneiform is relatively large; proximally it displays a broad concavity for the ulna, while the distal face is occupied by the large subcircular facet for the unciform. The pisiform facet is flat and notably small, whereas in *Oreodon* it is concave and occupies the whole palmar side of the bone. The trapezium is somewhat of a surprise in its shape and connections; it

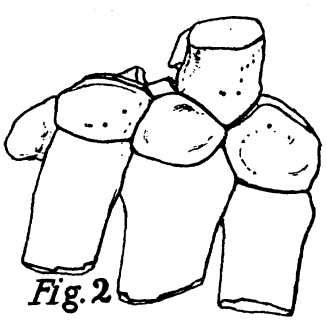

FIG. 2. Part of left manus of *A. major*? Nat. size. The trapezium is incorrectly placed, the surface in contact with the trapezoid being that for the scaphoid.

is a small nodular bone, which is attached to the scaphoid and trapezoid, but has no facet for a first metacarpal. In view of the fact, indicated by Osborn and Wortman, and confirmed by one of the specimens received from Mr. Hatcher, that a hallux was present in the pes, the absence of the pollex, which is preserved in at least two oreodonts, is decidedly unexpected. There is reason to believe, however, that the pollex was retained in *A. antiquus*. The trapezoid is considerably larger than the magnum, especially its dorsal portion ; posteriorly it is excavated on the ulnar side for the extension of the magnum. The surface for the scaphoid is somewhat warped ; broad and proximal in front, narrower and obliquely lateral behind. The distal portion of the trapezoid articulates only with the second metacarpal. The magnum differs from that of *Oreodon* in several important respects. Its proximal surface is occupied principally by the lunar, the scaphoid being confined to a relatively narrow surface in front, though posteriorly the contact is more considerable, and further the magnum has but a very small facet for the second metacarpal. The unciform differs considerably from that of *Oreodon*. Anteriorly the lunar facet forms an excavation upon the radial side of the bone, but posteriorly an almost cylindrical process extends beneath the lunar. The proximal surface, which in *Oreodon* is divided equally between the lunar and cuneiform facets, is occupied almost entirely by the facet for the cuneiform. The articular surface for the fifth metacarpal differs from that of the last-named genus in its larger relative size and more distal position, and the posterior hook of the unciform is decidedly more massive.

The metacarpals are represented by the proximal and distal ends of the second and fourth and by the third complete. They display several significant differences from those of *Oreodon*. As already mentioned, the pollex was probably entirely absent and the other metacarpals are of more uniform size, giving a more isodactyl form of manus than in *Oreodon*. The head of mc. II is slightly smaller than that of mc. IV, and has a large concave facet for the trapezoid and a very minute one for the magnum. The shaft is more rounded and less antero posteriorly compressed than in *Oreodon*. The distal end is creodont rather than ungulate in appearance. This appearance is due to the great enlargement of the processes for attachment of the lateral ligaments, the more distinct constriction of the trochlea and its almost spherical shape and to the greater prominence of the carina. Mc. III is the heaviest of the series ; it bears a large facet for the magnum, which is convex antero-posteriorly and concave transversely, and abuts against the unciform by a process which overlaps the head of mc. IV ; this process is, however, relatively smaller than in *Oreodon*. Mc. IV requires no particular description ; it is rather smaller than mc. III and somewhat larger than mc. II.

The phalanges are, at first sight, very different from those of *Oreodon*, but a careful comparison shows important resemblances, especially if the small species, *A. antiquus*, from the lower beds be considered. In the proximal phalanx the following differences from *Oreodon* may be observed : (1)

The proximal articular surface is more deeply concave, and more oblique to the long axis of the bone, presenting dorsally as well as proximally. (2) The distal trochlea is less depressed, more deeply notched and extends farther upon the palmar side. In the second phalanx the dorso-palmar diameter is relatively much greater and the transverse diameter less than in *Oreodon*. The median ridge of the proximal trochlea is much more prominent and the lateral concavities of this surface more deeply excavated. The distal articular facet is much more extensive, especially upon the palmar side, and more deeply notched in the middle line. The ungual is compressed and forms a large claw, quite unlike the slender pointed hoof of *Oreodon*, though the difference is hardly a fundamental one. The facet for the second phalanx is much greater in the dorso-palmar direction and allows a more extended movement of the two bones upon each other. The mutual relations of the three phalanges is quite different in the two genera; in *Agriochœrus* the arrangement is much like what is found in *Chalicotherium*.

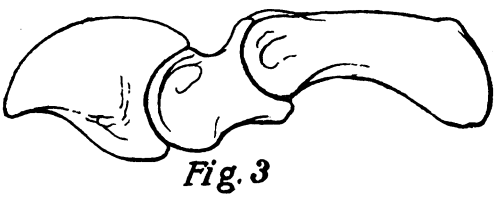

Fig. 3

FIG. 3. Phalanges of IV digit of manus. Same individual as Figs. 1 and 2, nat. size.

The tibia differs in several important respects from that of *Oreodon*. The proximal end is carnivorous rather than ungulate in appearance. This is due partly to the flatness of the condyles and their slighter obliquity from before backward, but especially to the small prominence of the cnemial crest, which though broad and massive is much lower than in *Oreodon*, and hence the proximal portion of the tibia has a decidedly smaller antero-posterior diameter than in that genus; the spine is also less conspicuous. The distal end is remarkable for the great size of the internal malleolus, which is very long and has an articular facet for the astragalus upon its free end.

The tarsus has already been fully described by Osborn and Wortman. It is requisite here, therefore, only to call attention to the differences which obtain between the various species of *Agriochœrus*, as well as between the latter genus and *Oreodon*. In the absence of teeth it cannot yet be determined whether the specimen described by Osborn and Wortman should be referred to any of Leidy's species and therefore, for the purposes of the present comparison, the name *A. gaudryi* O. and W. will be retained. *A. antiquus* from the Oreodon beds differs from *A. gaudryi* in the following particulars: (1) The size is somewhat smaller. (2) All the elements of the tarsus are relatively higher and narrower. (3) There is less difference in size between the internal and external condyles of the astragalus and the latter is separated by a much wider interval from the cuboidal facet. (4) The pit for the internal malleolus is much less deeply

incised. (5) The fibular facet of the calcaneum is higher and more oblique, but less extended antero-posteriorly. (6) The calcaneal facet of the cuboid is relatively broader, while that for the astragalus is narrower. Unfortunately the compound cuneiform is lost from the specimens of *A. antiquus* and the only navicular preserved is too much injured for comparison.

The tarsus of *Agriochœrus* is fundamentally similar to that of *Oreodon*, but with many significant differences of detail. Comparing *O. culbertsoni* with *A. antiquus* the following deviations in the structure of the latter may be observed. (1) All the tarsal bones are much lower and broader. (2) The pit on the astragalus for the tibial malleolus is much deeper and the ridge separating the cuboid and navicular facet of this bone is decidedly more prominent. (3) The sustentaculum of the calcaneum is much more strongly developed and projecting. (4) The calcaneal facet descends lower upon the dorsal face of the cuboid; the hook-like process on the plantar surface of the cuboid is very much more massive and the distal facet for the fifth metatarsal less distinctly separated from that for the fourth. In *A. gaudryi* the plantar hook of the navicular is greatly increased in breadth as compared with that of *O. culbertsoni*, and on the distal surface of the compound cuneiform the facets for the second and third metatarsals lie in the same transverse plane, instead of being at different levels. In consequence of this arrangement the second metatarsal, which in *Oreodon* abuts against the tibial side of the ectocuneiform, is entirely excluded from that element. Whether the same is true of *A. antiquus* cannot at present be determined. In one of the specimens of the latter species the entocuneiform is preserved. It is considerably wider than the same bone in *Oreodon*, and has a distal facet for the first metatarsal, thus confirming Osborn and Wortman's observation as to the presence of a hallux in this genus. A number of caudal vertebræ show that *Agriochœrus* had a longer and more powerful tail than *Oreodon*; indeed, the tail is quite as well developed as in the larger cats, *e. g.*, the leopard. I have elsewhere called attention to the curious character of the axis in this genus (*Morphologisches Jahrbuch*, Bd. xvi, p. 361). The odontoid process has the characteristic shape found in the oreodonts; it is short and broad, with strongly convex ventral surface, nearly flat dorsal surface, and rounded anterior margin. This process is, therefore, neither conical nor spout-shaped, but intermediate between the two. The neural spine, on the other hand, is entirely different from that of the oreodonts and forms a great hatchet-shaped plate, resembling carnivorous rather than ungulate structure.

The Systematic Position of Agriochœrus.

Leidy separated this genus from the oreodonts, as the type of a distinct family, which he regards as a "peculiar and extinct family of ruminants of the most aberrant character, but allied to the *Oreodonts*." Gill united the two families, giving to *Agriochœrus* subfamily rank, an example which

was followed by Cope and by myself. Osborn and Wortman referred their genus *Artionyx* to the Ancylopoda with *Chalicotherium*, constructing a new suborder, the Artionychia, for its reception. While much remains to be learned regarding *Agriochœrus*, some inferences from the facts of structure described in the preceding pages are reasonably clear. In the first place, I cannot agree with Osborn and Wortman in removing this genus altogether from the Artiodactyla and assigning it to the Ancylopoda. Such a removal implies that all of the artiodactyl features of structure have been independently acquired, and this is highly improbable. I have, it is true, repeatedly insisted upon the reality and frequency of parallelism in development, but it is very easy to push this doctrine to unwarranted extremes. Among mammals, at least, no such extreme case of this mode of evolution is known as would include the skull, dentition, limbs, carpus and tarsus, and in fact everything but the phalanges. The only evidence which could justify such a conclusion would be the finding of a succession of species by which the independent origin of the two groups could be traced out step by step. The agreement of *Agriochœrus* with *Chalicotherium* is of the slightest and most superficial character, consisting only in the fact that both genera have claws. But the ungual phalanges are of a very different pattern in the two genera, and it is surely the less dangerous horn of the dilemma to conclude that this single correspondence is due to parallelism rather than that the numerous and important characters in which *Agriochœrus* agrees with the artiodactyls are the result of such a process.

But a difficulty arises here; is not the distinction between hoof and claw a fundamental one, established long before the artiodactyls had arisen? To answer this question with any certainty would require a much more exact knowledge of the genesis of both kinds of phalanx than we at present possess, but there is much reason to believe that while the ungulate and unguiculate types of mammals are radically distinct, yet the distinction does not rest, as the names imply, upon the character of the unguals. At all events both hoof and claw are found in closely allied genera, as for example, among the rodents, creodonts and edentates. These examples are, it is true, all found among the unguiculates, but there is no *a priori* reason for assuming that a similar diversity among the ungulates may not occur. That it is rare in the latter group is doubtless due to the fact that ungulates almost uniformly employ the feet only for purposes of locomotion, and indeed it is difficult to conjecture what the function of such feet as those of *Agriochœrus* and *Chalicotherium* may have been. In view of all the characteristic artiodactyl structures which *Agriochœrus* displays, one can hardly escape the conclusion that in this case the transition from hoof to claw has actually taken place and that this genus is the culmination of a series of aberrant artiodactyls. In the second place it is obvious that Leidy's separation of *Agriochœrus* from the *Oreodontidæ* is entirely proper. A more obscure problem is to determine the relationship between the two families, and to this end it will be necessary to briefly

recapitulate their resemblances and differences. *Agriochœrus* resembles the oreodonts in the following points: (1) The skull structure of the two families is closely alike and the Uinta genus *Protoreodon* hardly differs at all in this respect from *Agriochœrus*. (2) The very characteristic oreodont features of the caniniform first lower premolar and incisiform canine are repeated in *Agriochœrus*. (3) The atlas and the peculiar odontoid process of the axis are similar in both groups. (4) The elbow joint in the oreodonts is, as is well known, very exceptional among ungulates and all its peculiarities are repeated in somewhat exaggerated form in *Agriochœrus*. (5) The tarsus is oreodont in almost every particular, and is curiously paralleled in many details by that of the Loup Fork genus *Merycochœrus*. It should be remembered in this connection that in *A. antiquus* the tarsus deviates less from the oreodont type than does that of the later and larger *A. gaudryi*, and is in fact intermediate between the two. This is significent, because in the long continued existence of the *Oreodontidæ* from the Uinta to the Loup Fork, there is relatively little change in the tarsus, while each successive genus displays its own particular modification of the carpus. (6) The phalanges, except the unguals, differ relatively little in the two groups and are manifestly of the same type. (7) The articulations of the metapodials are similar.

The most important respects in which *Agriochœrus* differs from the oreodonts are as follows: (1) The pattern of the molar teeth is very distinct, but this gap, especially as regards the lower teeth, is to some extent bridged by *Protoreodon* of the Uinta Eocene, which shows that the two kinds of molar may well have been derived from a single type. (2) The distal end of the radius is creodont, rather than ungulate in character. (3) In *Agriochœrus* the carpus differs decidedly from that of the White River oreodonts, both in the shape and in the connections of its parts, the displacement being in opposite directions. Here again *Protoreodon* tends to connect the two extremes and displays a type of carpus not far removed from that which may have given rise to both. (4) The position of the phalanges with reference to the metapodials and to each other is quite different. (5) Much the most remarkable difference between the two groups is the presence of claws in *Agriochœrus*, while the oredonts have hoofs. (6) Though the large *Agriochœrus* species from the uppermost White River beds has no pollex, there is reason to believe that it was present in the earlier and smaller *A. antiquus*. (7) A striking difference in the knee-joint is observable between *Agriochœrus* and the oreodonts, which indicates that in the former the leg was straighter, while the proximal end of the tibia and distal end of the femur have quite the appearance of the same parts in the Carnivora. (8) All the elements of the tarsus are lower and broader, the astragalus has a deep pit for the internal malleolus and a hallux is present. The latter has not been found in any oreodont. (9) Another carnivorous feature in *Agriochœrus* is the shape assumed by the neural spine of the axis.

In brief, the dentition and skeleton of *Agriochœrus* show a large num-

ber of close correspondences with the oreodonts and especially in those particulars in which that group differs from other artiodactyl families. On the other hand, there are significant deviations from the oreodonts, which are to be found more particularly in the structures correlated with the curious change in foot structure. It seems on the whole highly probable that the two families are not distantly related, especially if the somewhat intermediate character of *Protoreodon* be considered.

The conclusion to which the available evidence leads is, then, that *Agriochœrus* is the last term in a succession of species which form a curiously specialized offshoot of the *Oreodontidæ*, its divergences from that family being principally the results of a change in the functions and uses of the feet. The separation of the two series was probably already established in the Uinta Eocene, for, in spite of its somewhat intermediate character, *Protoreodon* can be a forerunner only of the oreodonts. The Bridger beds may be expected to yield the common ancestor of the two series, and this animal will probably turn out to be a pentadactyl form, with buno-selenodont dentition and quinquetuberculate upper molars, the unpaired lobe in the anterior half of the crown. As I have elsewhere suggested, this hypothetical form may have been already found in the imperfectly known *Helohyus*.

The likeness of the *Agriochœrus* molars to those of *Hyopotamus* has often been noticed and the inference drawn that these two genera were in some manner more or less closely related. Mr. Hatcher writes me that he has lately found feet of *Hyopotamus* which suggest the same affinities. Until this material has been carefully studied, it will be the part of prudence not to prejudge the question.

Three New Methods for the Detection of Forgery.

By Dr. Persifor Frazer.

(*Read before the American Philosophical Society, May 18, 1894.*)

I wish to put on record three new methods which I have applied successfully for the purpose of detecting frauds in written documents.

The first enables one to determine with comparative ease which of two crossing ink lines was made first, and consists in observing the crossing by a lens of low power (four or five diameters) at a very oblique angle. If a light ink line be made over a darker one the appearance to the eye when viewing the crossing perpendicularly to the plane of the paper will be that the darker line is superposed. The reason of this is that ink lines are quite transparent and the darker line is seen through the lighter one and seems to make one continuous line with its two limbs